SST and Mixed Layer Depth Variability in Upwelling Regions

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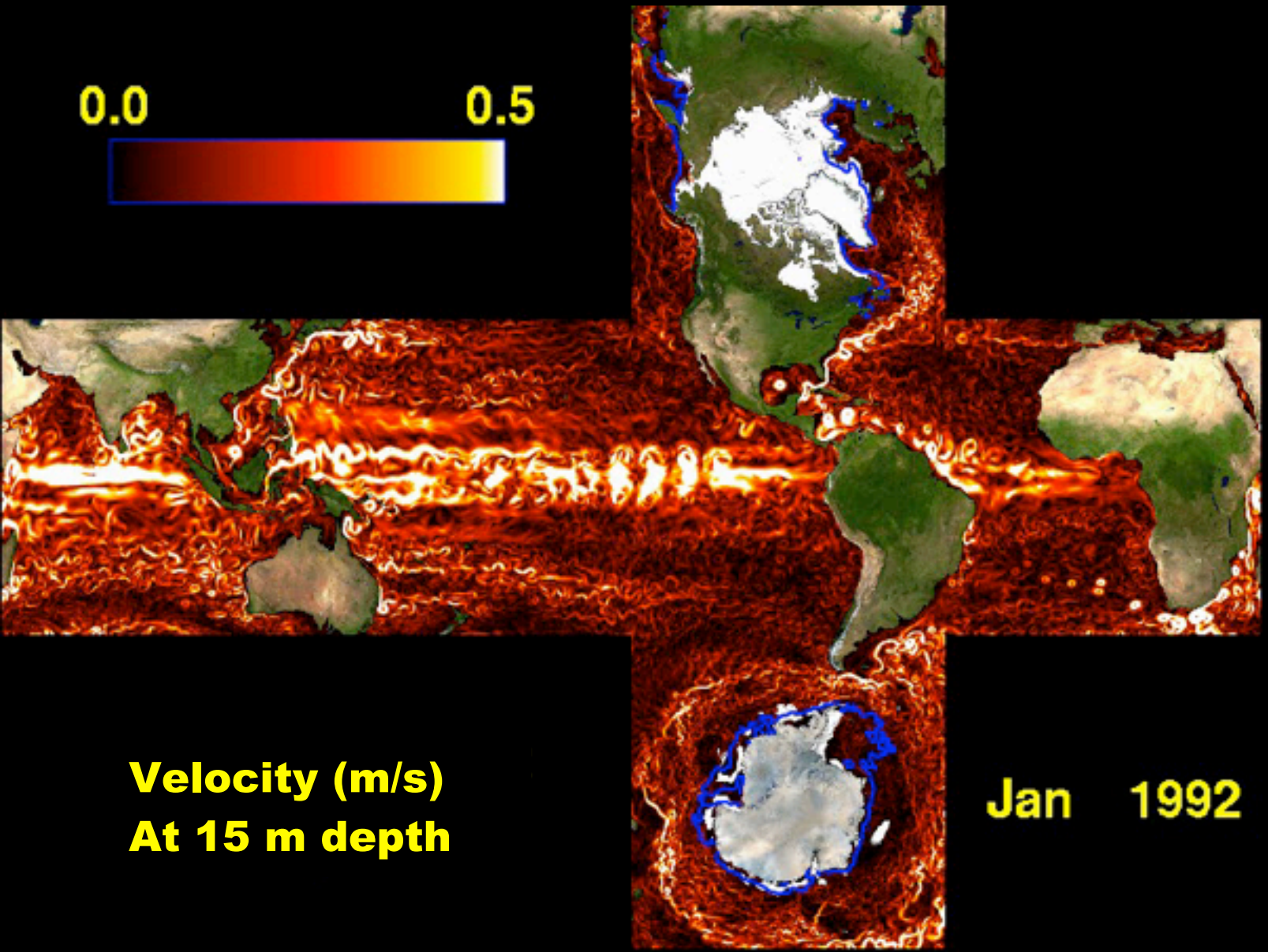
ECCO2: High-Resolution Global-Ocean and Sea-Ice Data Synthesis

Objective: synthesis of global-ocean and sea-ice data that covers the full ocean depth and that permits eddies.
Motivation: improved estimates and models of ocean carbon cycle, understand recent evolution of polar oceans, monitor time-evolving term balances within and between different components of Earth system, etc.



Forward model:

- MITgcm
- cubed-sphere configuration
- 18-km horizontal grid
- 50 vertical levels
- modified Leith viscosity
- KPP vertical mixing
- dynamic-thermodynamic sea ice

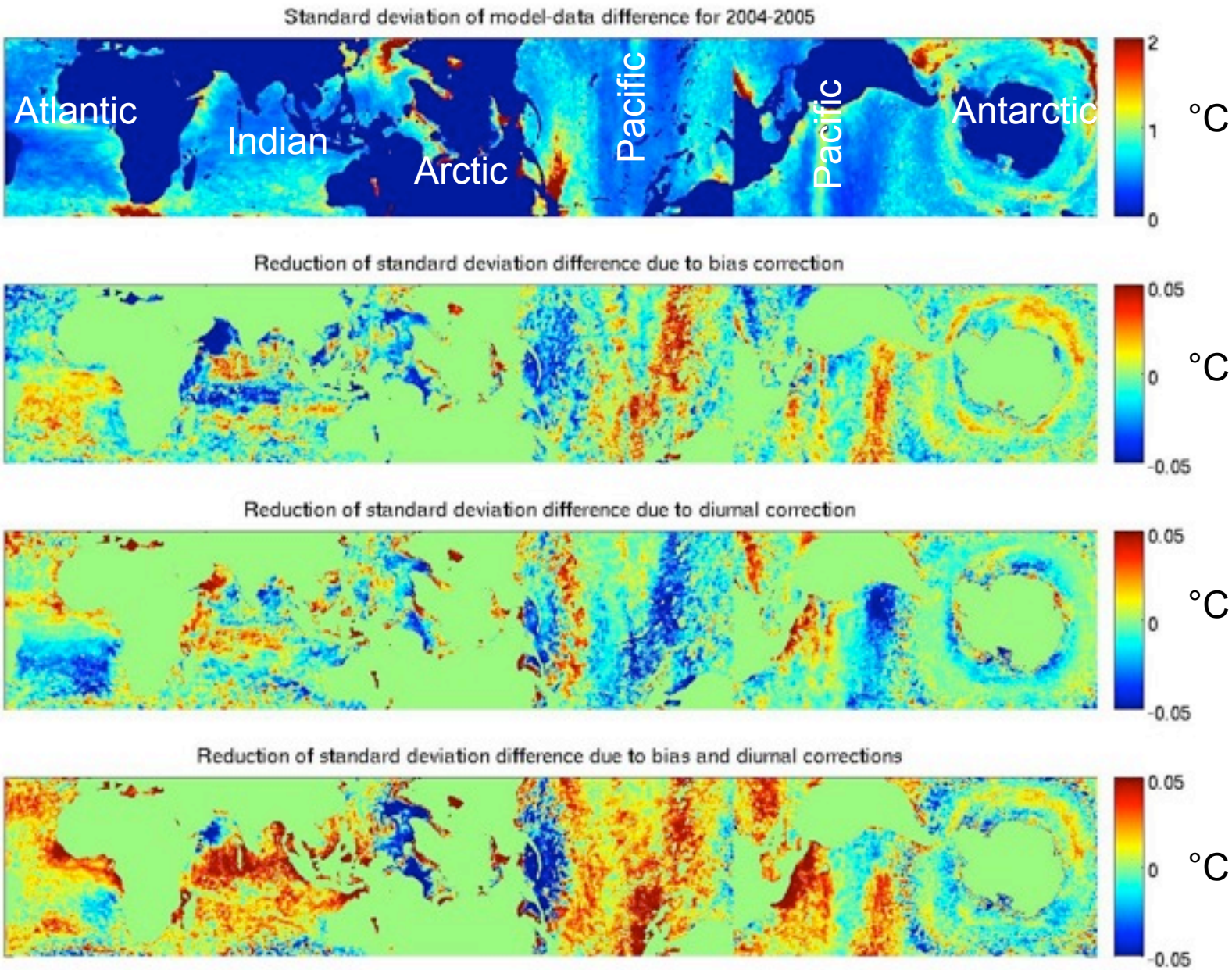
Standard deviation of model-data difference for 2004-2005

σ (model-data)

σ explained by bias

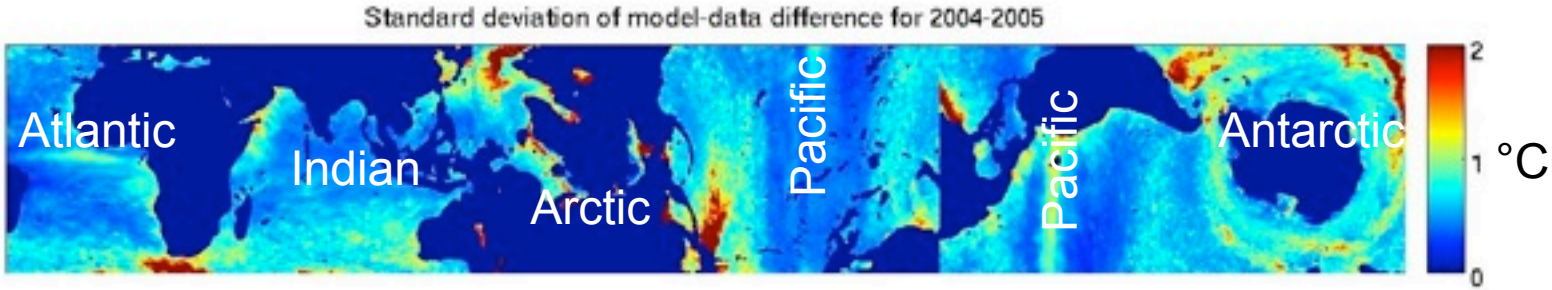
σ explained by diurnal

σ explained bias + diurnal

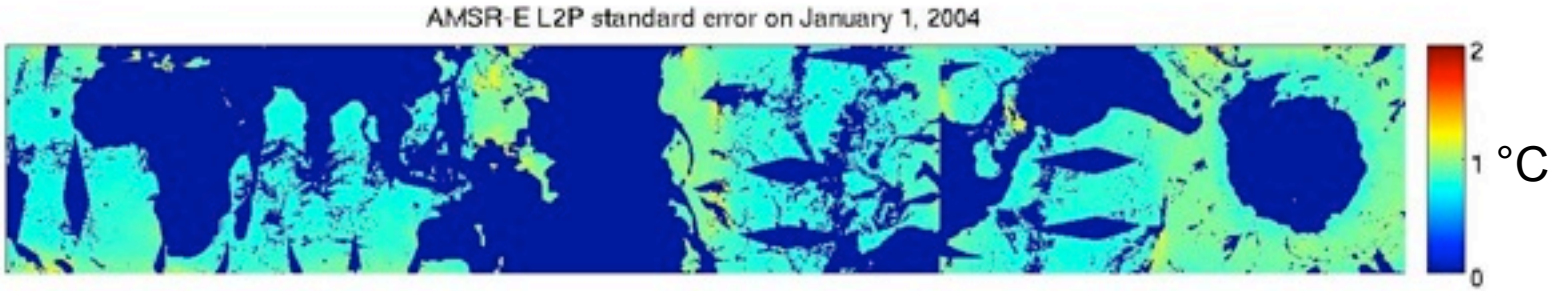


Data error specification for cost function

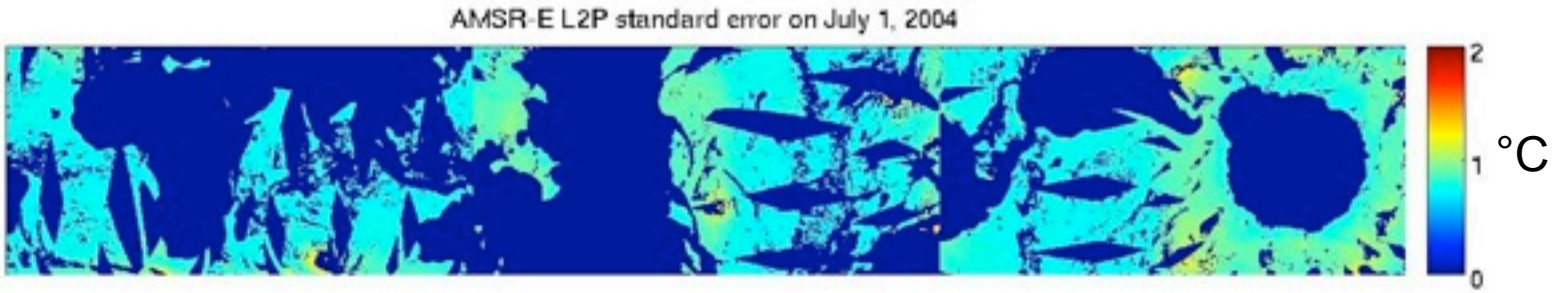
σ (model-data)



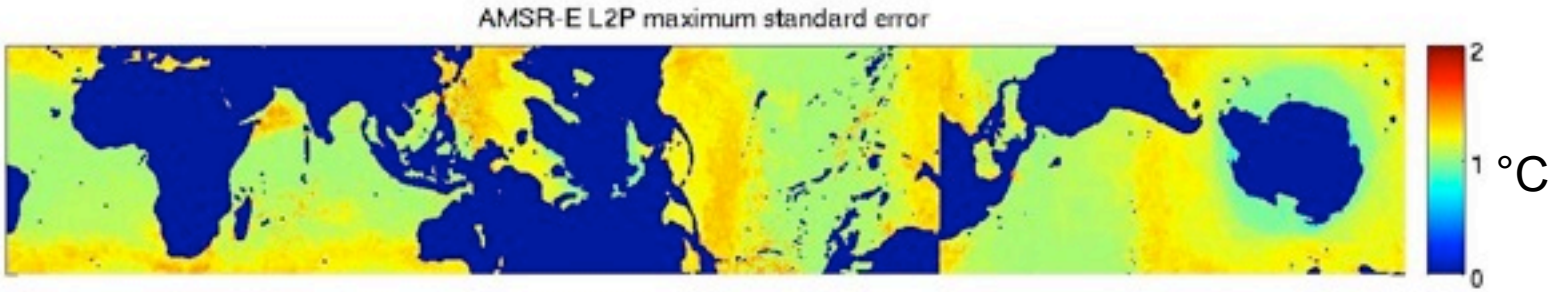
AMSRE standard error on 1 Jan 04



AMSRE standard error on 1 Jul 04

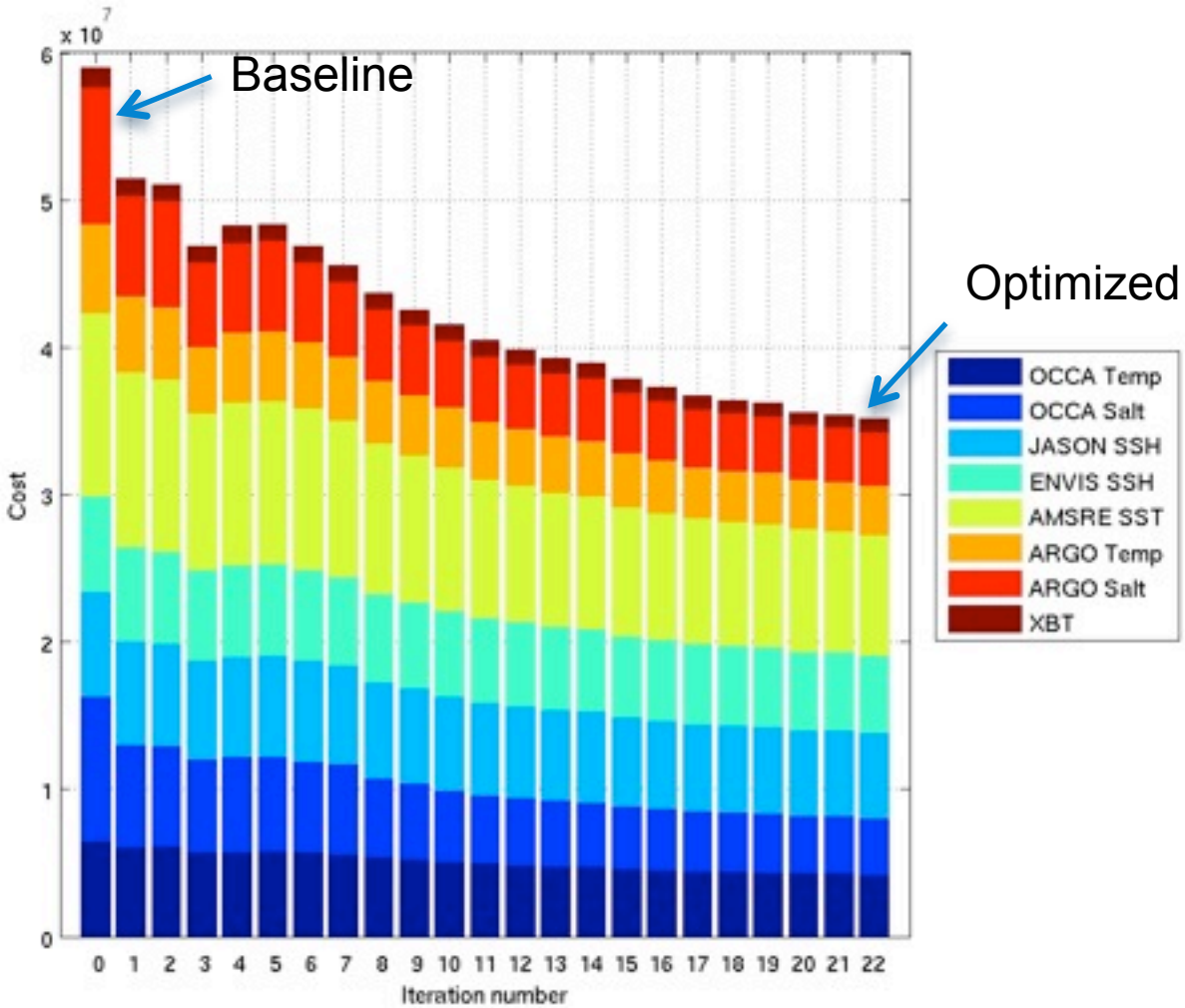


AMSRE max standard error



Eddying, global-ocean, and sea ice solution obtained using the adjoint method to adjust ~10^9 control parameters

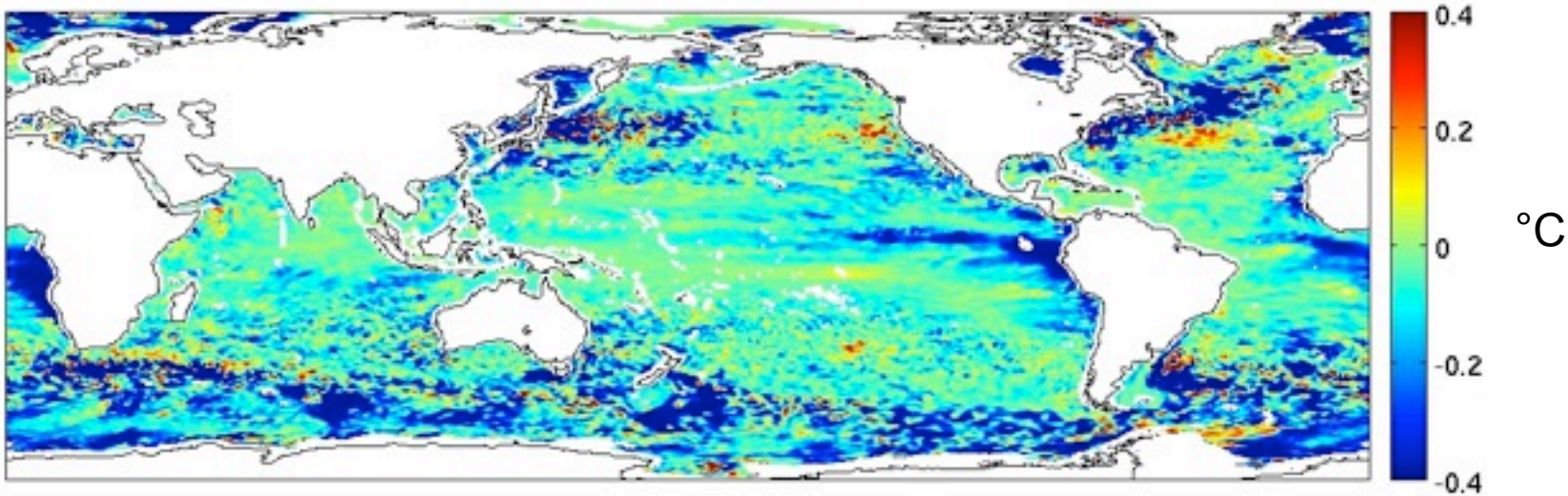
Cost functions reduction during first 22 forward-adjoint iterations



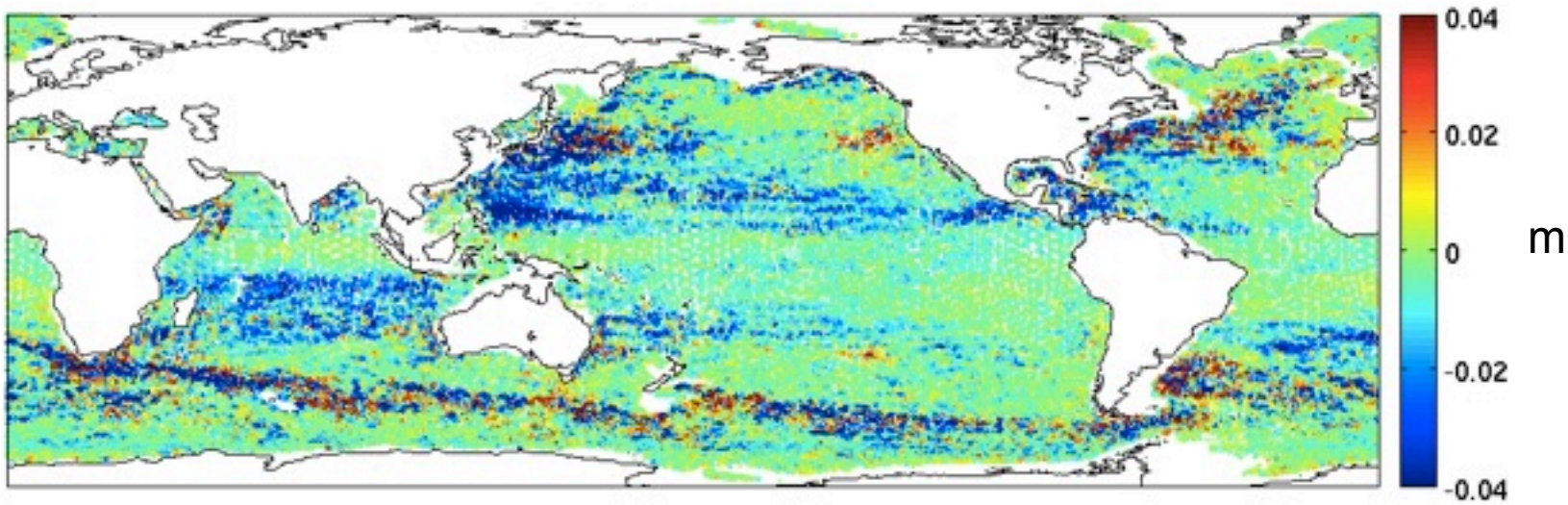
- Baseline solution derived from optimized Green's function solution and OCCA (Forget 2010) climatology
- Optimization period is beginning of ARGO-rich period (January 2004 to April 2005)
- Huge computation: ~1 week per forward-adjoint iteration on 900 CPUs and 3.6 TB of RAM
- 41% overall cost function reduction after 22 forward-adjoint iterations

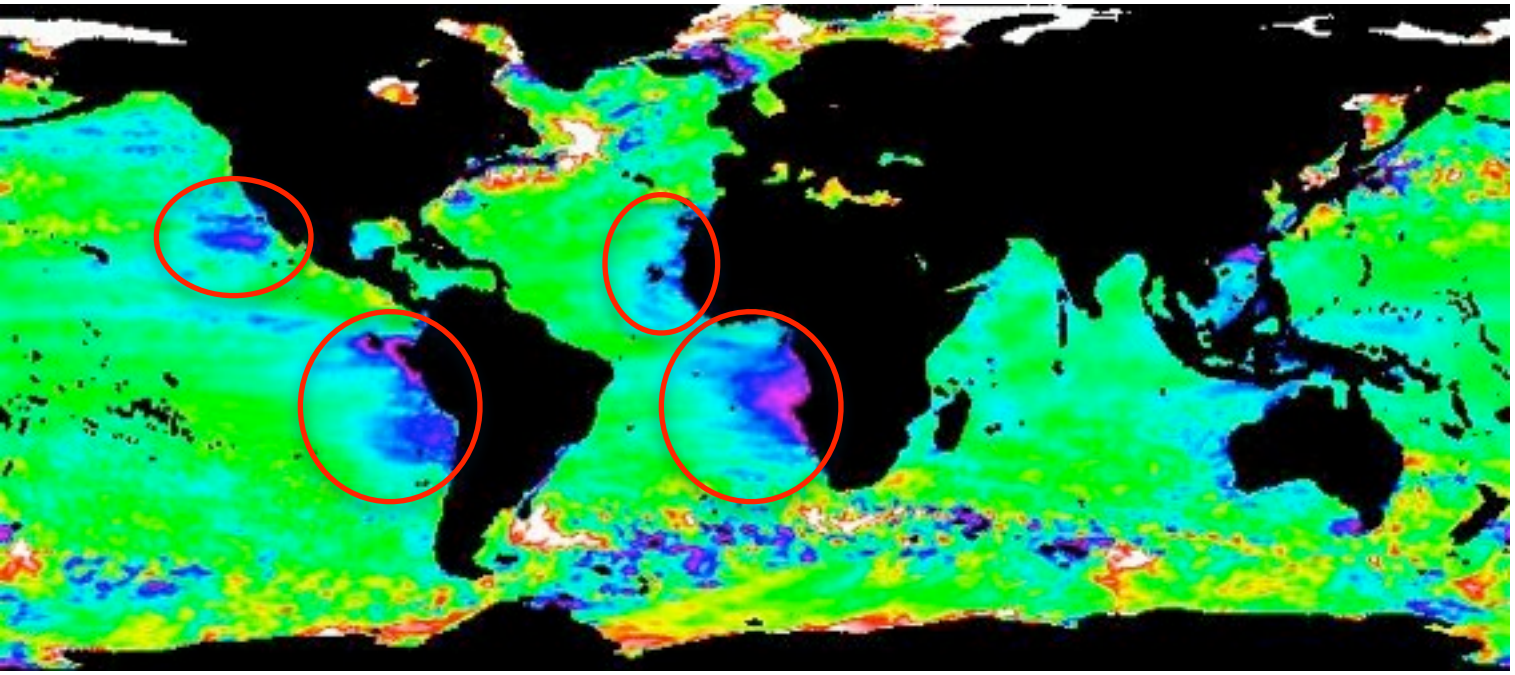
Reduction of root-mean-square model-data residual

rms(Optimized – AMSRE SST) – rms(Baseline – AMSRE SST)

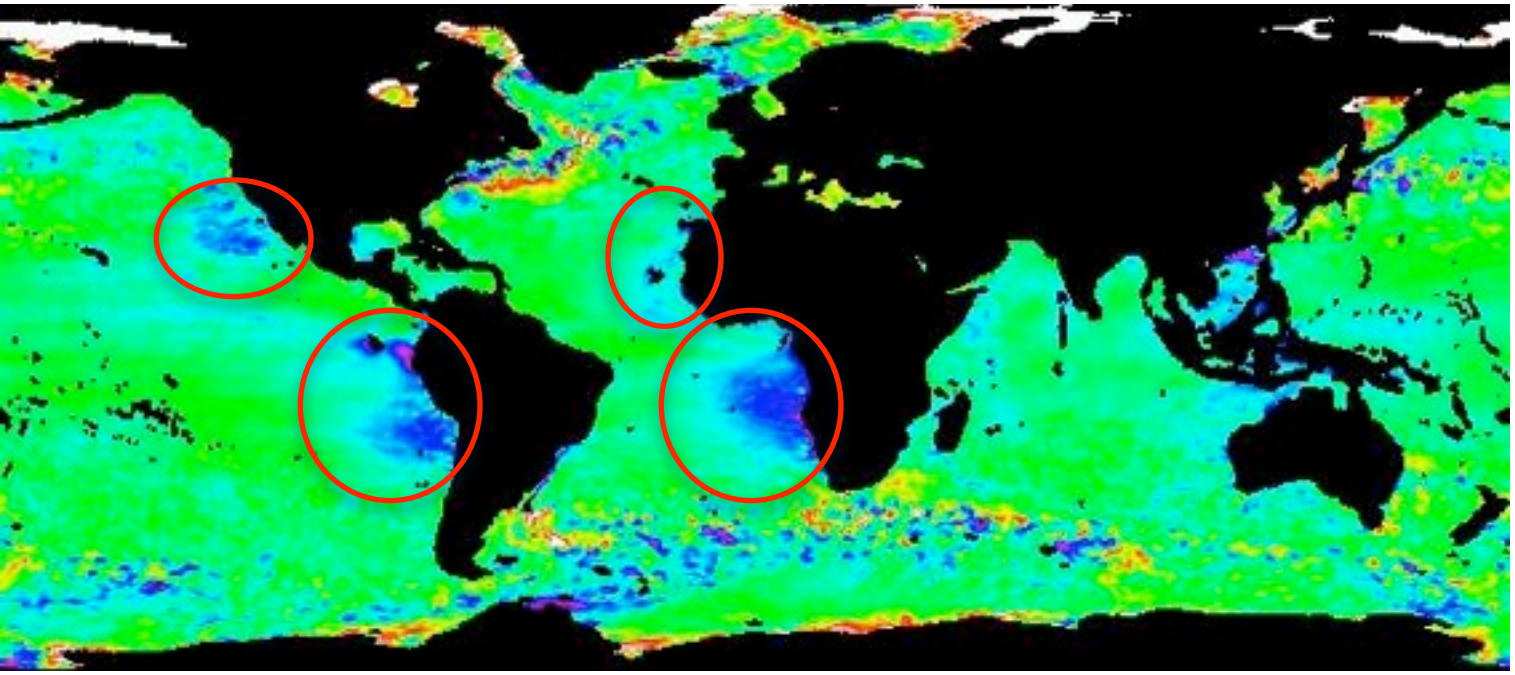


rms(Optimized – ENVISAT SSH) – rms(Baseline – ENVISAT SSH)

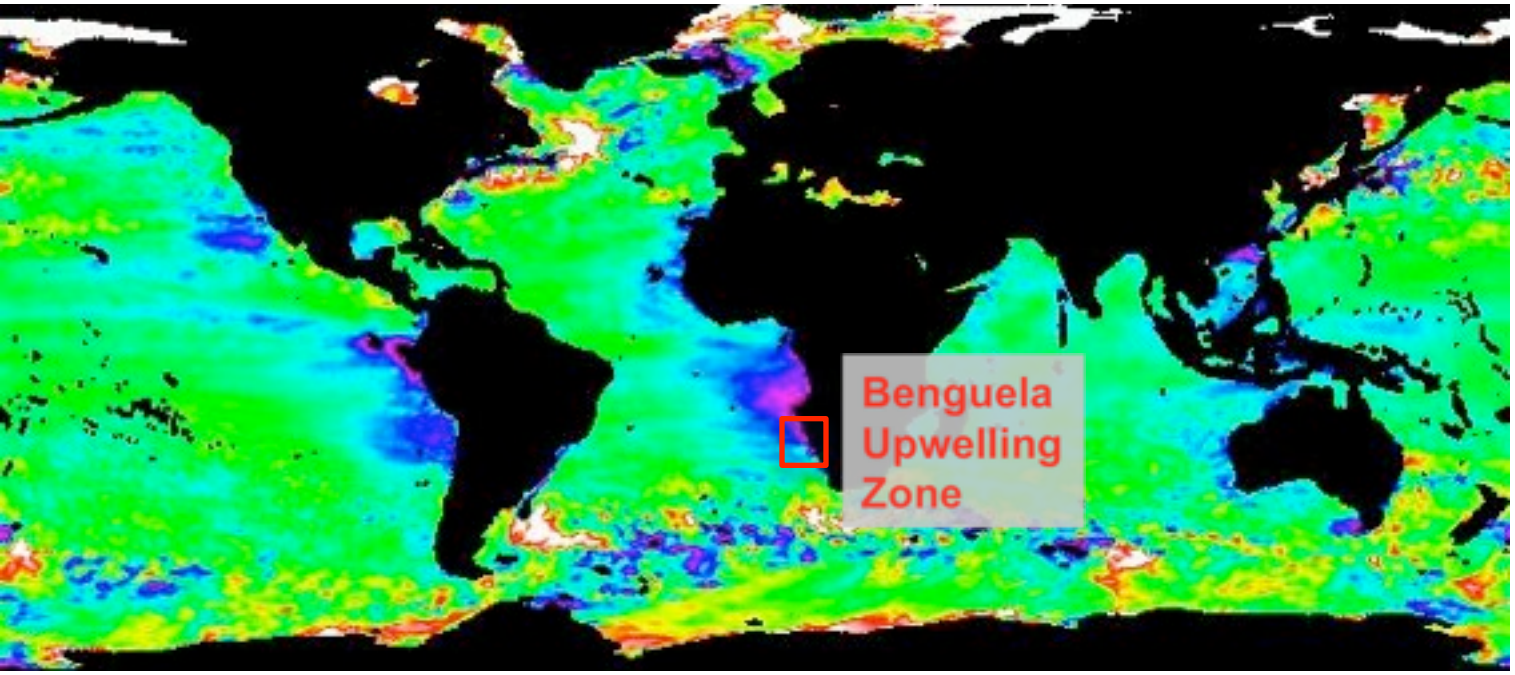




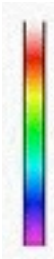
Mean AMSR-E
minus Baseline

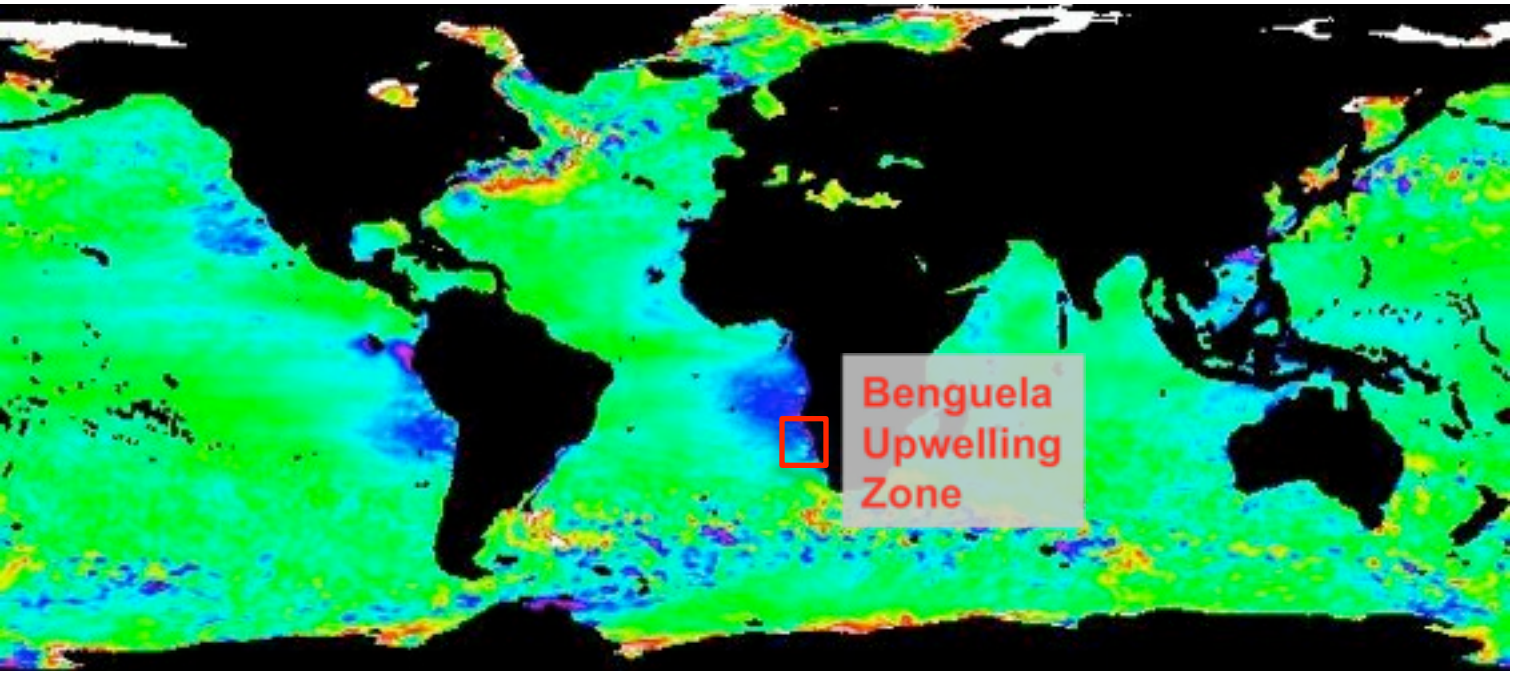


Mean AMSR-E
minus Optimized

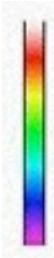


Mean AMSR-E
minus Baseline

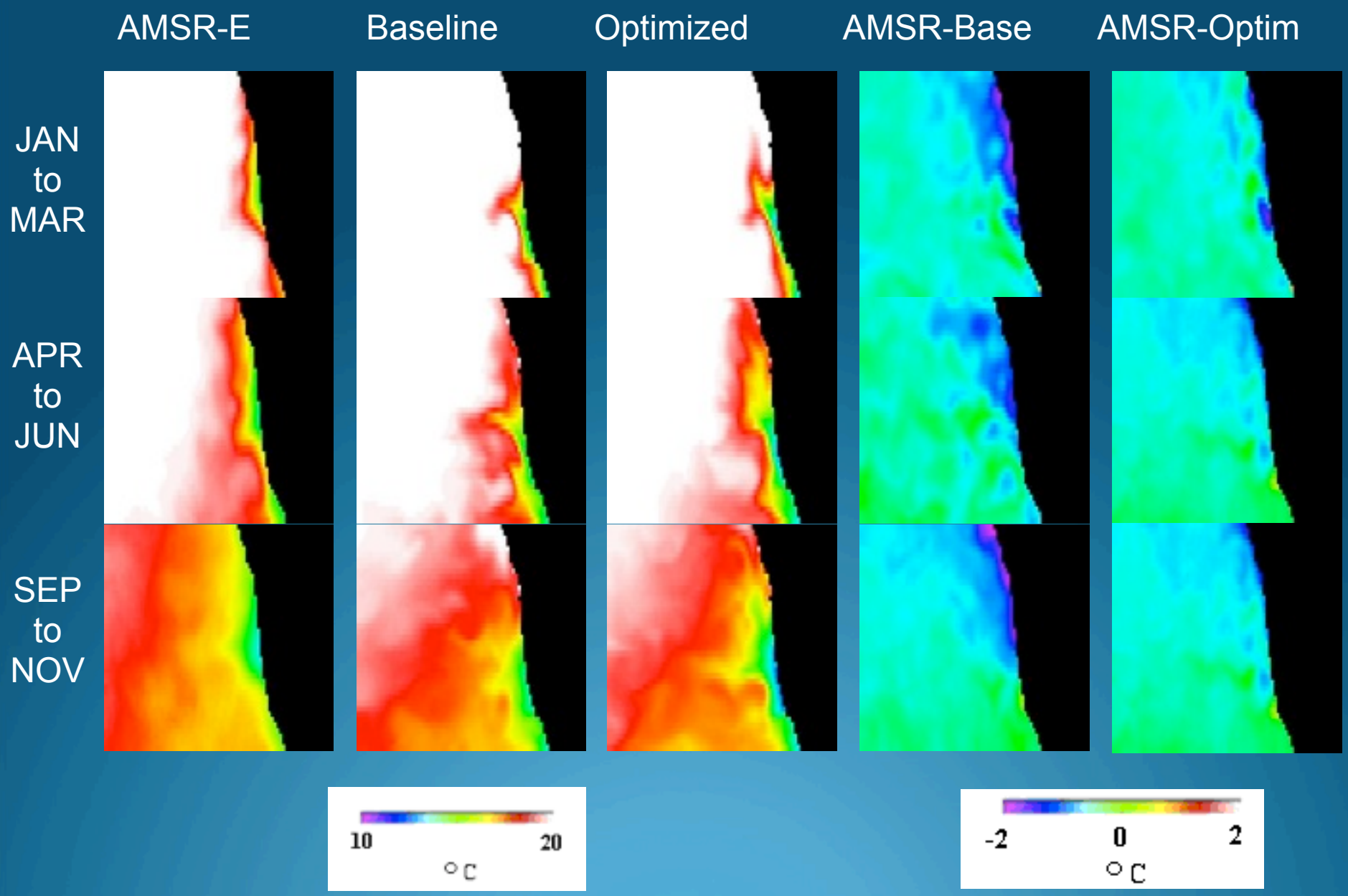


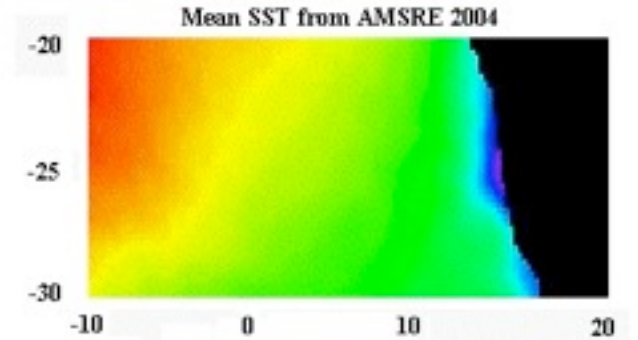


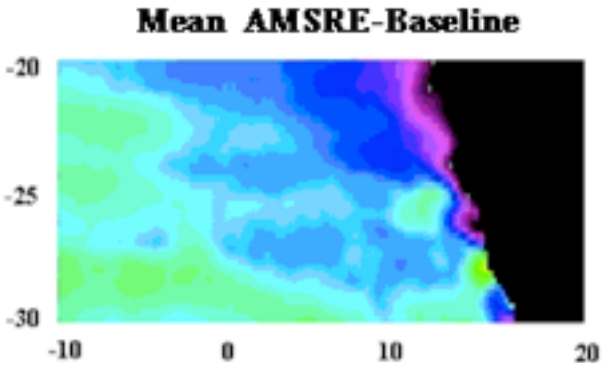
Mean AMSR-E
minus Optimized

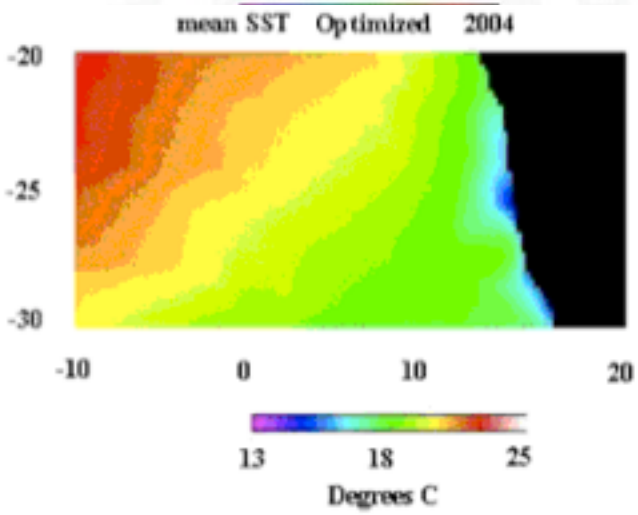


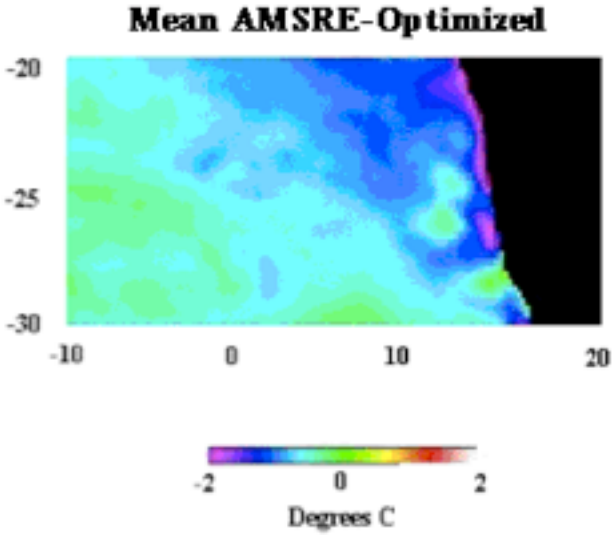
2004 Sea Surface Temparature

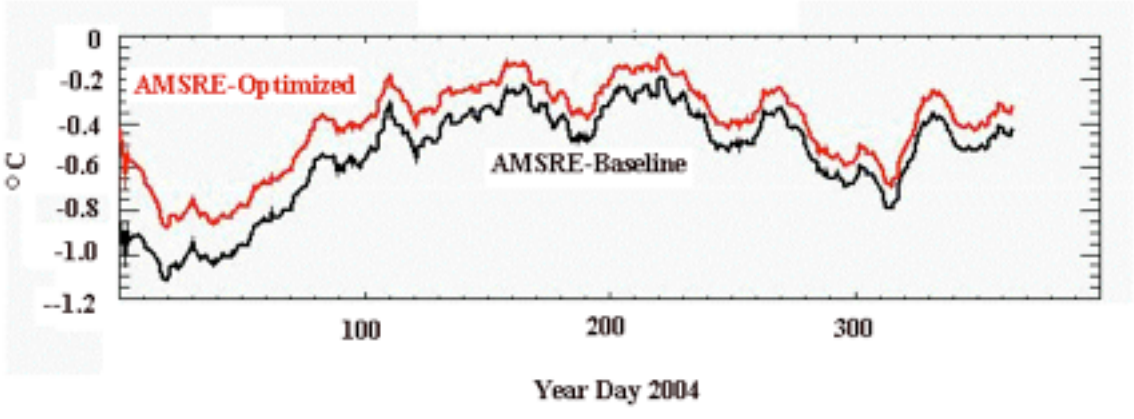



Mean SST from AMSRE 2004
-20
-25
-30
-10
0
10
20

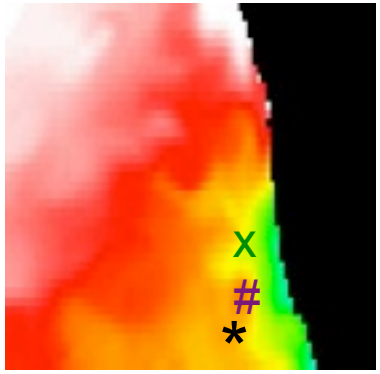

Mean AMSRE-Baseline
-20
-25
-30
-10
0
10
20

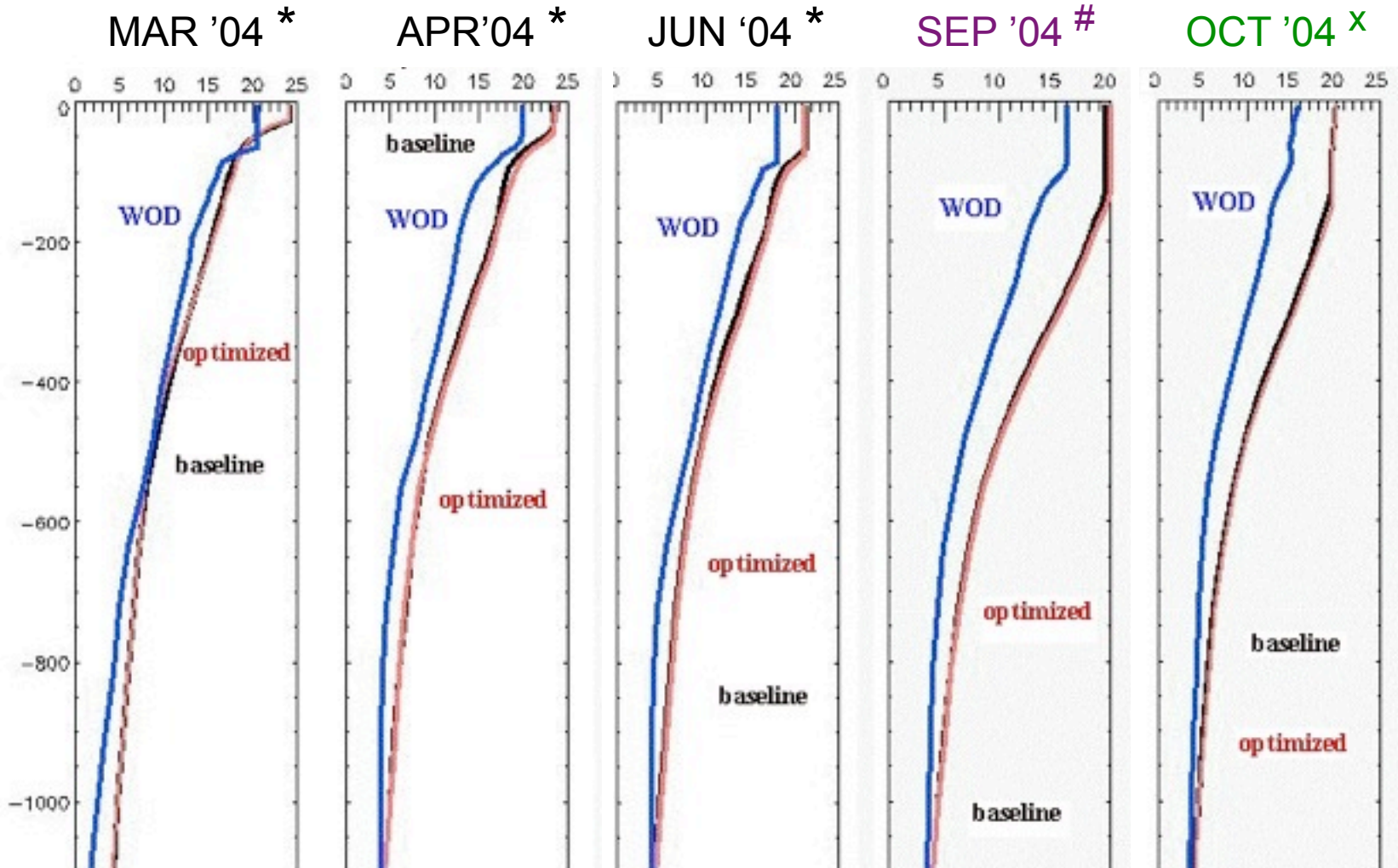

mean SST Optimized 2004
-20
-25
-30
-10
0
10
20
13
18
25
Degrees C


Mean AMSRE-Optimized
-20
-25
-30
-10
0
10
20
-2
0
2
Degrees C

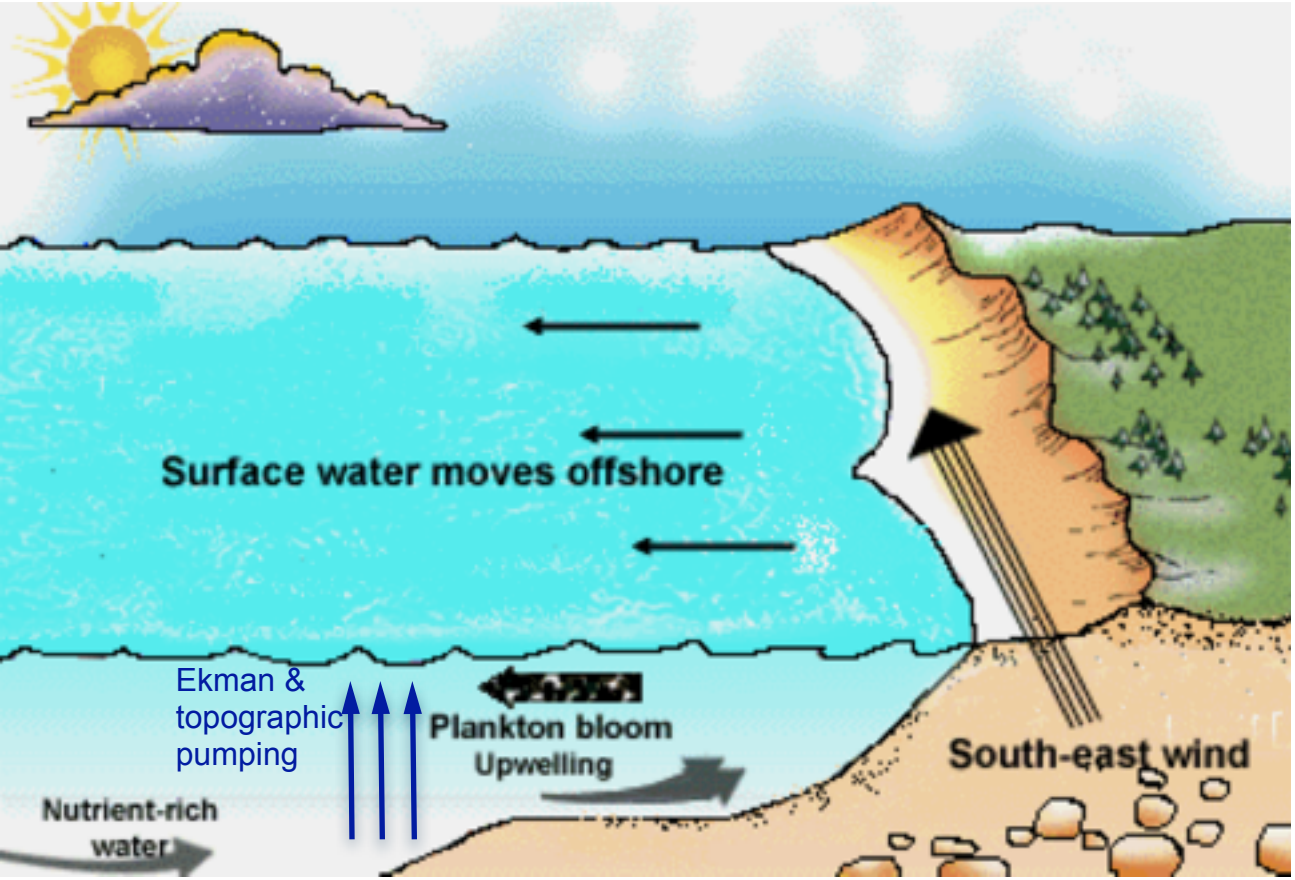

AMSRE-Optimized
AMSRE-Baseline
0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
° C
100
200
300
Year Day 2004

Temperature profiles in Benguela Upwelling Zone





Benguela Upwelling Zone



Ekman pumping

$$w_e = -\nabla \times \boldsymbol{\tau} / \rho f$$

$\boldsymbol{\tau}$: wind stress

ρ : water density

f : Coriolis parameter

Coastal upwelling

$$w_c = -c\tau_y e^{-y/a} / \rho g' H$$

c : internal wave speed

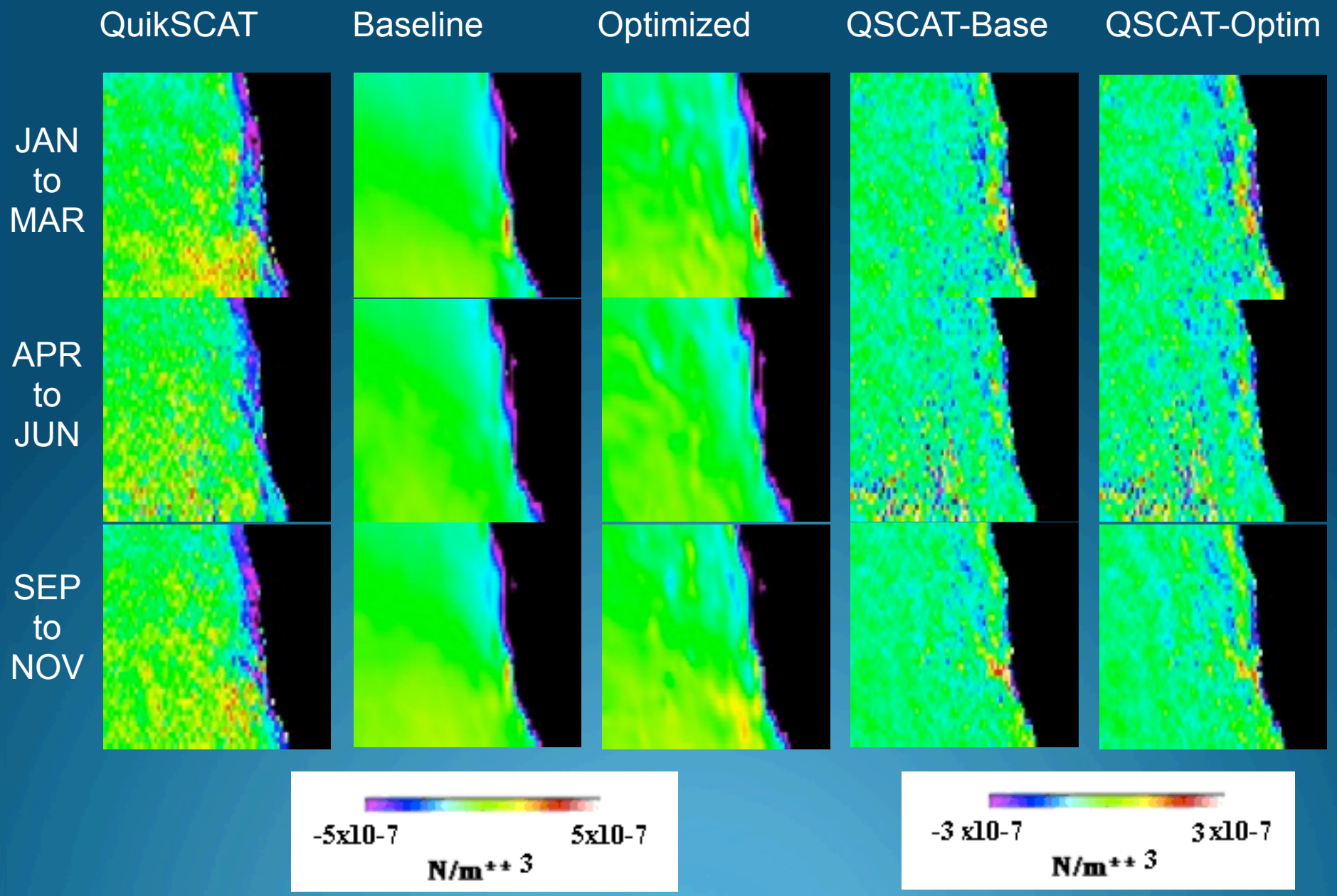
τ_y : longshore stress

g' : reduced gravity

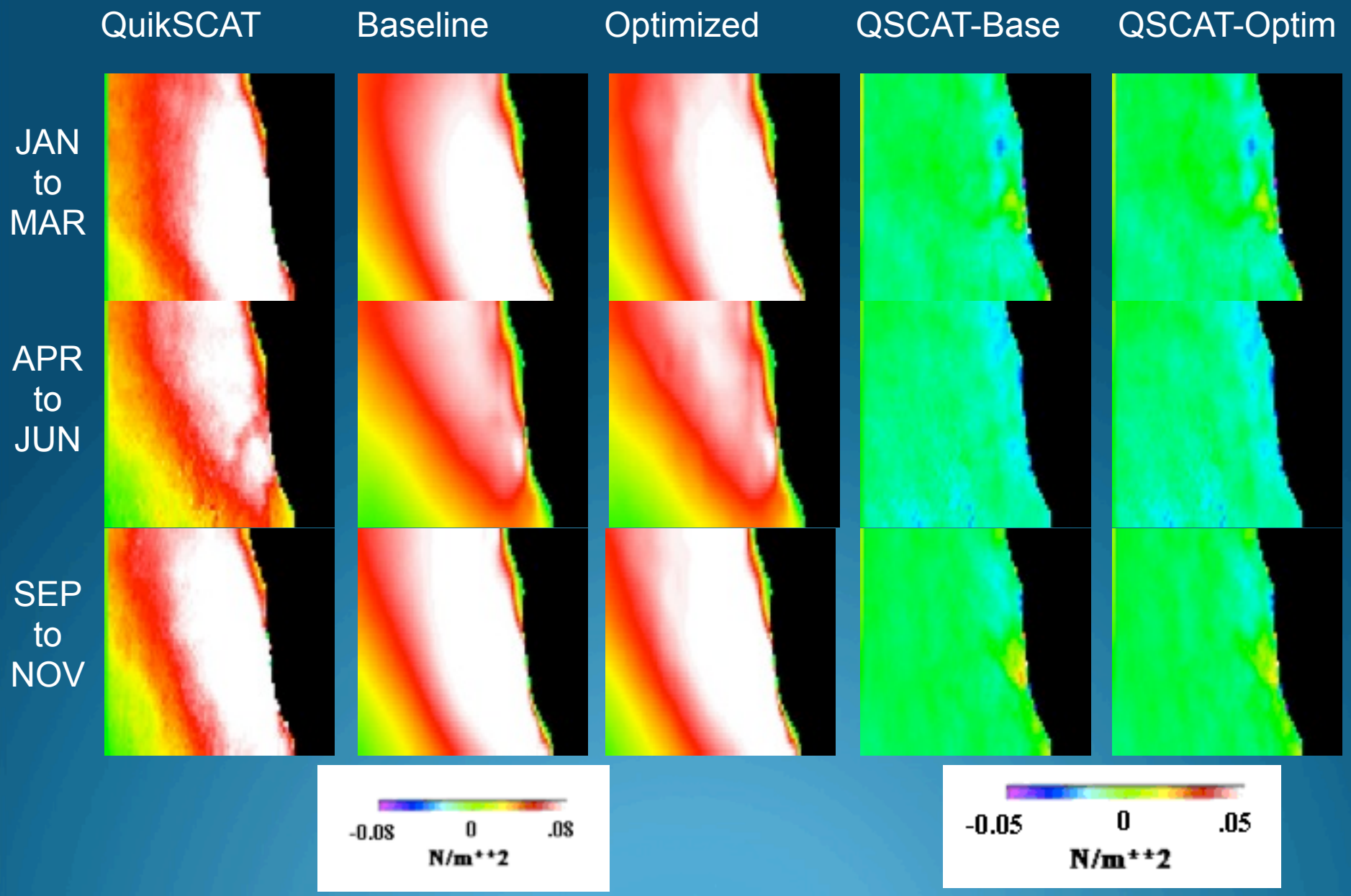
H : mixed layer depth

a : Rossby radius

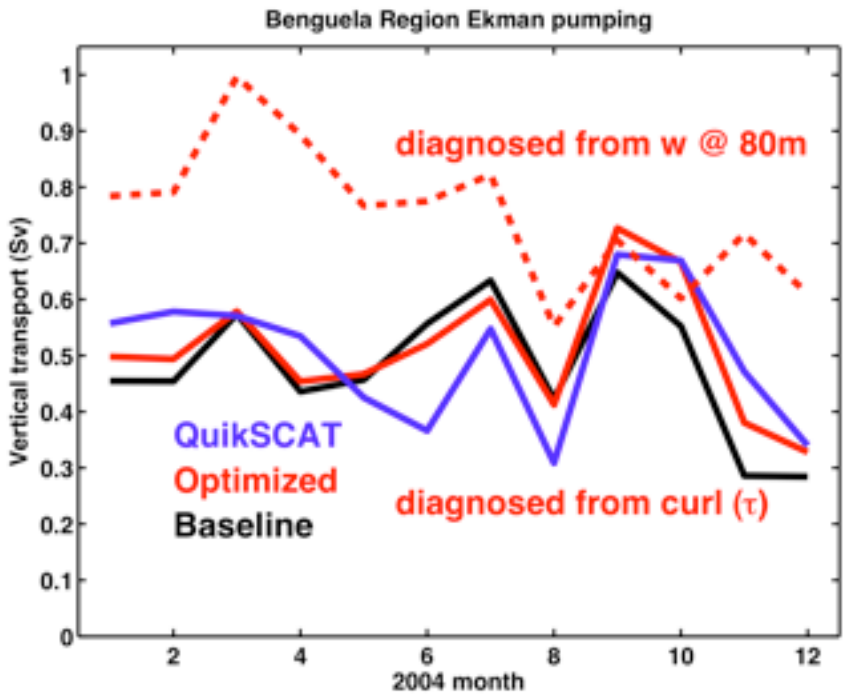
2004 wind stress curl

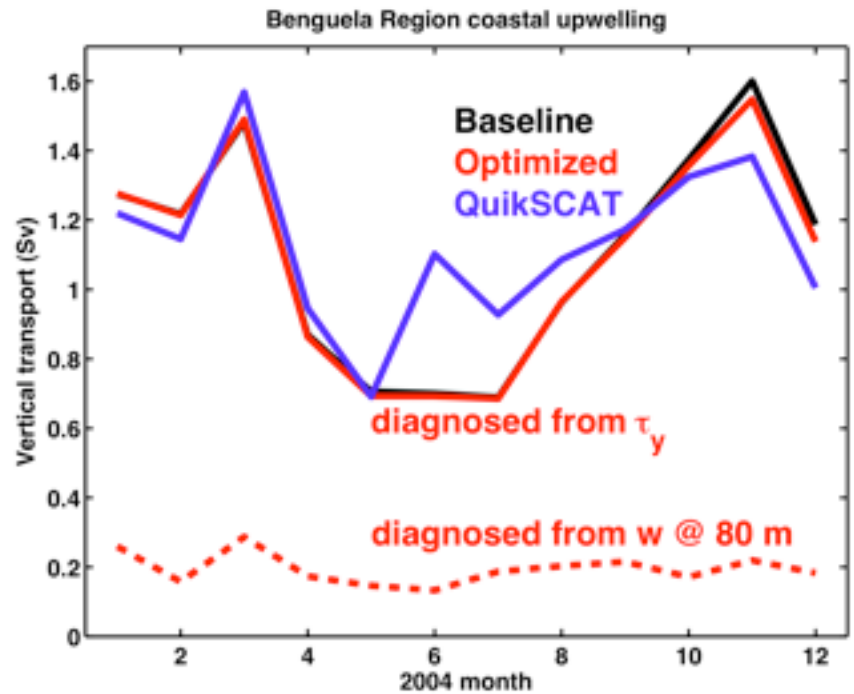


2004 Meridional wind stress



Benguela Region Upwelling





Ekman pumping

$w_e = -\nabla \times \boldsymbol{\tau} / \rho f$

(within 200 km of coastline)

Coastal upwelling

$w_c = -c\tau_y e^{-y/a} / \rho g' H$

(a = 26 km)

Summary and concluding remarks

- GHRSST AMSR-E data were used to evaluate and constrain ECCO2 eddying ocean state estimates using the adjoint method.
- Significant negative biases (AMSR-E colder than ECCO2) are observed in areas of known upwelling.
- Estimated wind stress curl and longshore winds in Benguela Upwelling Zone are within 20% of QuikSCAT retrievals.
- Wind stress curl contributes ~1/3 of total upwelling.
- Cold temperature bias in baseline and optimized ECCO2 solutions results in part from weak (~1/2 theoretical value) upwelling.
- Aim to improve representation of coastal upwelling in global GCMs.